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VARIATION IN RESISTANCE OF HARD PINES TO MOUSE DAMAGE

The most rapid progress in forest-tree improvement will be attained through artificial reforestation with superior genotypes. These trees may be native species, exotics, or hybrid combinations involving several species of diverse origins. Any tree planting creates an artificial situation, which is made even more artificial by the introduction of non-native types. In such situations, pests of various sorts—including certain mammals—may be much more destructive than elsewhere. One of the most neglected fields of inquiry bearing on plantation success concerns the role of mammals, especially rodents.

During the winters of 1959-60 and 1960-61, considerable rodent damage occurred in young hard pine plantations at the Hopkins Experimental Forest in Williamstown, Mass. On many trees the bark was gnawed near the ground line; degrees of damage varied from only slight injury to complete girdling of the stem (fig. 1). The feeding took place mainly during the winter under heavy snow cover. Type of damage, plantation site conditions, and limited trapping operations indicated that the destructive agent was the field mouse (*Microtus pennsylvanicus* Ord), also called the meadow vole.

Two adjacent plantations on the Hopkins Forest were especially hard hit. The trees in these plantings were all exotics—either accessions of known origin, or open-pollinated or hybrid progenies from exotic species growing in the area around Philadelphia, Pa. Plantation GP-2A-56 contained 24 seedlots, 22 of which were derived from Philadelphia plantings; the other two seedlots were accessions of *Pinus thunbergii* Parl. (Japanese black pine) from Japan and Korea. Plantation GP-2B-56 contained 8 seedlots: one each of *P. sylvestris* L. (Scotch pine) from Scotland, England, Austria, and Switzerland; *P. densiflora* Seib & Zucc. (Japanese red pine) from Japan and Korea; and *P. nigra* Arn. (European black pine) from Italy and from a planting near Philadelphia.

Figure 1.—A stem of Japanese black pine (*Pinus thunbergii*) completely girdled by field mice.



The seedlings were outplanted as 2-0 stock in the spring of 1956. Each plantation consisted of 20 replicated plots, each plot containing one tree from each seedlot represented in the plantation. The individual trees were randomized within plots at 6- by 6-foot spacing. This should have been excellent for the evaluation of mouse damage, since foraging animals were allowed considerable freedom of choice in their diets and could more readily exhibit their true food preferences.

In the spring of 1961, each tree that had been recorded alive in a survival tally in the fall of 1959 was examined for mouse damage done during the two intervening winters.

Analysis and Results

Although there was considerable tree-to-tree variation in severity of damage, simple comparisons of percentages of trees attacked clearly showed the variation in resistance among progenies and progeny groups (table 1).

For purposes of statistical analysis, each planting was divided into four blocks with each block containing five adjacent plots. Percent of trees attacked was calculated for each progeny in each block, based on numbers of trees living in the fall of 1959. (Progeny of the cross *P. thunbergii* \times *P. yunnanensis* were not included in the analysis because of the small number of surviving trees in 1959). The analysis of variance was performed on transformed values

(arcsin transformation) of the percents of trees attacked. In both plantations there were highly significant differences among progeny groups but no significant differences among seedlots within groups of similar parentage. The range test of Tukey (Snedecor, 1956) was applied to permit comparisons of means from different points in the array.

From the data for plantation GP-2A-56, several statistically and biologically significant comparisons can be made.

The hybrid between *P. thunbergii* and *P. tabulaeformis* Carr. (Chinese pine) was more resistant than pure *P. thunbergii*. *P. sylvestris* was the most resistant of all species or hybrids in the plantation and was significantly more resistant than the backcross progenies containing roughly $\frac{3}{4}$ *sylvestris* and $\frac{1}{4}$ *densiflora* germ plasm. *P. densiflora* was also more resistant than the backcross progenies composed of $\frac{3}{4}$ *densiflora* and $\frac{1}{4}$ *thunbergii* germ plasm.

It appeared from our data that each species possesses a certain degree of resistance to attack by the field mouse. For the species and hybrids studied, it is possible to construct a tentative resistance rating scale from most resistant to most susceptible as follows: *P. sylvestris*, *P. tabulaeformis*, *P. densiflora*, *P. thunbergii*, and *P. nigra*.

Table 1.—Mouse damage by progeny groups, 1959-61 among pine trees planted in 1956

Species or parentage ¹ (<i>Pinus</i> —)	Seedlot	Living trees; fall 1959	Trees attacked, spring 1961	
	No.	No.	No.	Percent
PLANTATION GP-2A-56:				
<i>thunbergii</i> x <i>yunnanensis</i> ²	2	5	3	60.0
<i>thunbergii</i> ³	5	41	22	{ 53.6 }
<i>thunbergii</i> x (<i>densiflora</i> x <i>thunbergii</i>)	6	82	42	
<i>densiflora</i> x (<i>densiflora</i> x <i>thunbergii</i>)	2	32	14	{ 43.7 }
<i>densiflora</i>	1	10	3	{ 30.0 }
<i>thunbergii</i> x <i>tabulaeformis</i>	4	66	13	
<i>sylvestris</i> x (<i>densiflora</i> x <i>sylvestris</i>)	2	40	5	{ 12.5 }
<i>sylvestris</i>	2	34	0	
PLANTATION GP-2B-56:				
<i>nigra</i>	2	38	31	81.6
<i>densiflora</i>	2	34	10	29.4
<i>sylvestris</i>	4	78	4	5.1

¹ In hybrid combinations the species used as the female parent is given first.

² Not included in analysis.

³ Brackets enclose progenies among which the damage was not significantly different at the 5-percent level.

Discussion

The results of our study disagree with findings of Littlefield, Schoomaker, and Cook (1946) in New York. In experimental plantings that included various pines, spruces, and larches, they found Scotch pine to be the species most heavily attacked by field mice. Among other exotic pines represented in both their plantings and ours, Japanese red pine, Japanese black pine, and Chinese pine were listed as more highly favored by mice, whereas Corsican pine (*P. nigra*) was less favored. Cayford and Haig (1961) reported that in Manitoba Scotch pine was highly susceptible to damage by field mice. They observed that minor site variations, particularly as expressed in type and density of ground cover, significantly influenced the degree of mouse attack.

The disparities between the above observations and our own exceed the range of variation in food preferences that might reasonably be expected among different mouse populations of the same species and among different environments, and we cannot satisfactorily explain them. We can only point out some circumstances that may influence the seemingly inconsistent food preferences of mice at different times and places.

Trees do not appear to be a favorite mouse food, and mice probably attack trees only when the supply of more favored foodstuffs is insufficient for the population. And food preferences are relative, varying with the supply of foodstuffs of differing palatability in relation to demand. Plantings of any tree species in large blocks would tend to force mice to utilize the trees that were available if they were at all palatable. Comparisons between species growing on different sites and in blocks of different sizes thus might lead to erroneous conclusions regarding species preferences. In our plantations, the single-tree randomization would seem to have been an optimum design for mouse-preference evaluation. However, in the above-cited New York and Manitoba plantings, the reported species differences in susceptibility to mouse damage cannot be attributed entirely to pure-block plantings. At both places, stripwise mixed plantings of two or more species also were involved, and Scotch pine in such mixtures was consistently damaged more than associated species.

The differences among species and hybrids in susceptibility to mouse damage lead to speculations about the controlling factors—what makes one species more palatable to a mouse than another? In our study the pattern of variation among the various progenies suggests that susceptibility (or resistance) is, at least in part, under genetic control. Since no constant relationship was found between damage and morphological or growth characters, the next logical place to look for a clue was in the chemical constituents of the young pine stems. Interest in a possible chemical basis for resistance

was further spurred by the publication of Mirov's (1961) compilation of information on the turpentines in pines.

Oleoresins are found in all living parenchyma cells of pines, but chiefly in the epithelial cells surrounding resin canals in the cortex and wood. Thus the resins are readily encountered by gnawing rodents. Oleoresins are made up of rosin and turpentine. Although the proportions of the component chemicals in the turpentine fraction doubtless vary to some extent, the basic composition of the turpentine is constant within species, and hybrids between species presumably contain turpentine constituents of both parents. Genetic rather than environmental factors are considered to play the major role in compositional variations.

From our observations and Mirov's turpentine analyses, evidence can be adduced for a hypothesis that accounts for resistance on a chemical basis. The evidence and supporting argument are as follows:

Scotch pine, the most resistant of all the species and hybrids in our study, is the only pine among them that is known to contain the highly reactive terpene, delta-3-carene. This raises the question of whether delta-3-carene is responsible for the resistance.¹ If this terpene is in fact an important factor in mouse resistance, tree-to-tree variability in its relative amounts would help to explain why a few Stoch pine trees were attacked. Also, we might infer that the increased susceptibility of *P. sylvestris* x (*densiflora* x *sylvestris*) resulted from reduction in the percentage of delta-3-carene to a point where it was comparatively ineffective in inhibiting mouse attack.

The question now arises as to the cause of the differences in resistance among the other progenies. Alpha-pinene is common in the turpentines of most pine species, and probably confers no specific capacity for differential behavior among species. However, the amount of alpha-pinene is a guide to the relative proportions of other substances. Damage in the progenies studied follows closely the amount of alpha-pinene in the turpentine: the higher the percent of alpha-pinene, the greater the percent of trees attacked. This relationship also holds true for Virginia pine, as compared to loblolly and pitch pines in Maryland (Fenton 1962): Virginia pine, which has a much higher content of alpha-pinene, was damaged much more by mice.

A hypothesis as outlined above—that delta-3-carene is associated with resistance, and that high percentages of alpha-pinene are associated with susceptibility—obviously is not supported by the observations of Littlefield, et al., and of Cayford and Haig. Therefore this hypothesis can be considered only as a first groping for a

¹ It has been noted that *P. brutia* Ten., a species containing delta-3-carene, is immune to the *Matsucoccus* scale insect; whereas the closely-related *P. halepensis* Mill., with none of this terpene, is susceptible (Mirov, 1961).

clue to the puzzle of what makes a species susceptible or resistant. Its value may lie mainly in stimulating further inquiry into the subject of chemical resistance factors.

More information on the chemistry of the oleoresins would be most helpful. The rosin acids and resenes of the rosin have not been studied intensively. Recent work by the senior author indicates that chemical differences exist between resin produced in the cortex and in the wood. Further research should help to elucidate the relationships existing between tree pests and the resins they encounter in their attack on pine trees.

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